Biologically Inspired Trunk and Tentacle Robots

Ian D. Walker

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Department of Electrical & Computer Engineering

CLEMSON UNIVERSITY

Overview

- Tongue. trunk, tentacle robots – biologically inspired
- Snakes and hard backbones
- Continuum trunks and soft tentacles
- Summary

Traditional Robotic Designs

Conventional Robots

- Traditional robots “anthropomorphic”
- Based around long rigid link elements
- Good for precision tasks in well structured environments
- Severely limited in cluttered environments
- Poor for adaptation to “unstructured tasks”

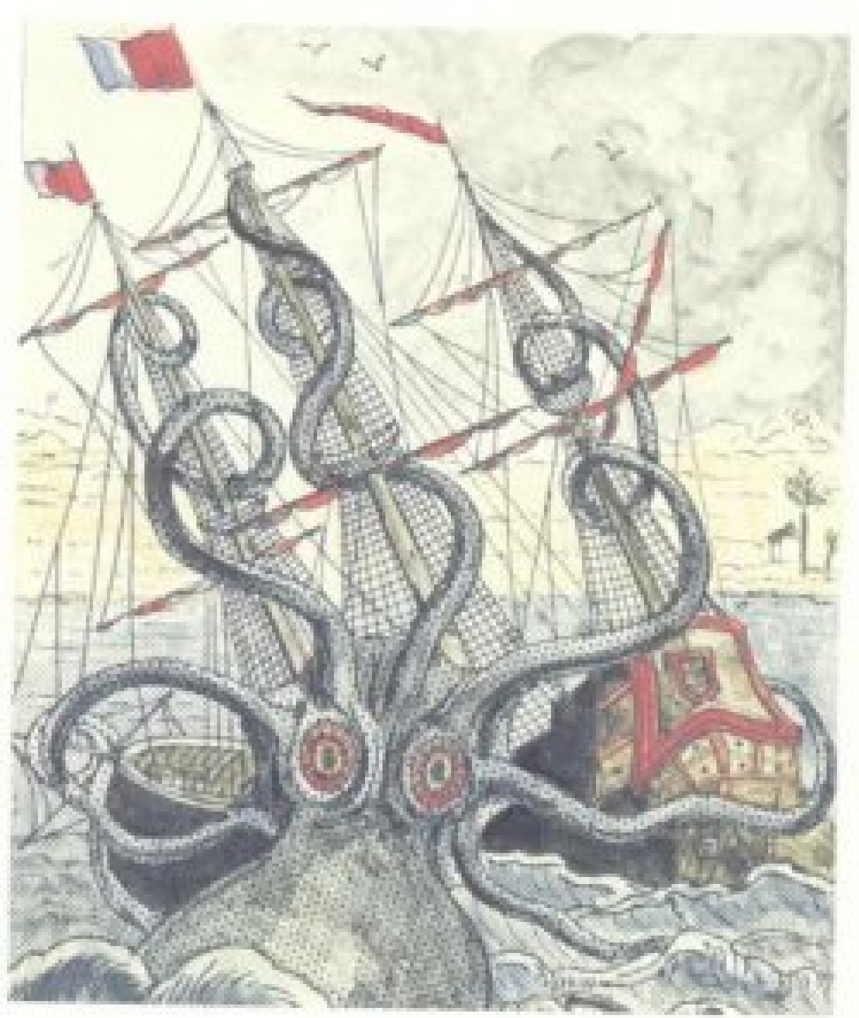
Trunk and Tentacle Structures

- More maneuverable backbone
- Can “wind around” environment better
- Enter, operate in tight spaces
- Envelop, grasp irregularly shaped objects

War of the Worlds, Paramount, 2005

Robot Trunks and Tentacles: How?

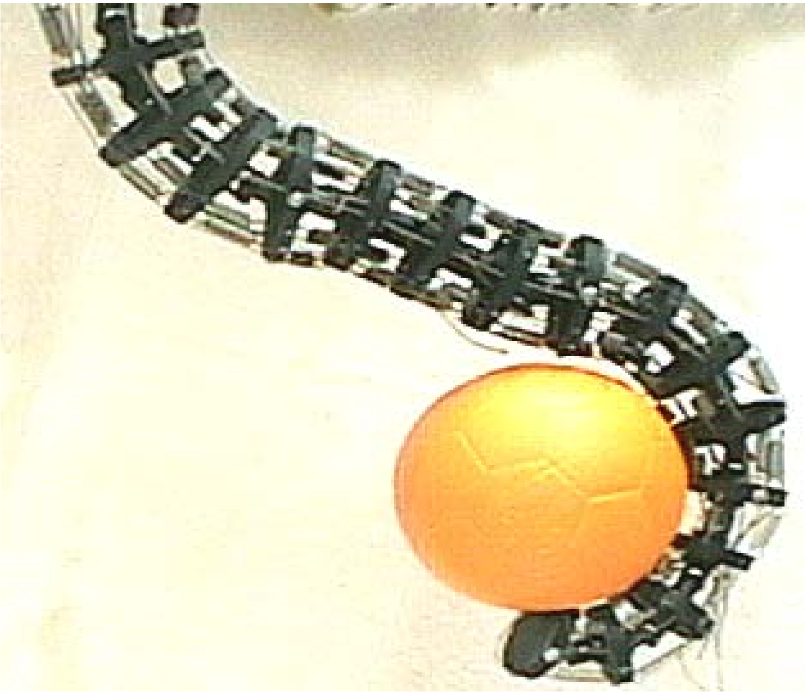
- Numerous examples in nature
- Vertebrate and invertebrate structures



Biological Inspiration – Elephant

- Motivation for our initial efforts at Clemson

Example: Clemson Elephant Trunk (~2000)



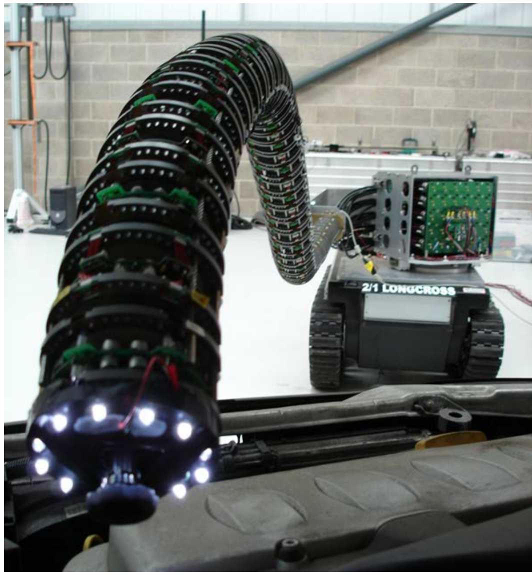
Biological Inspiration - Snakes

Tokyo Inst. Technology
(Prof. Shigeo Hirose et al)

Gavin Miller

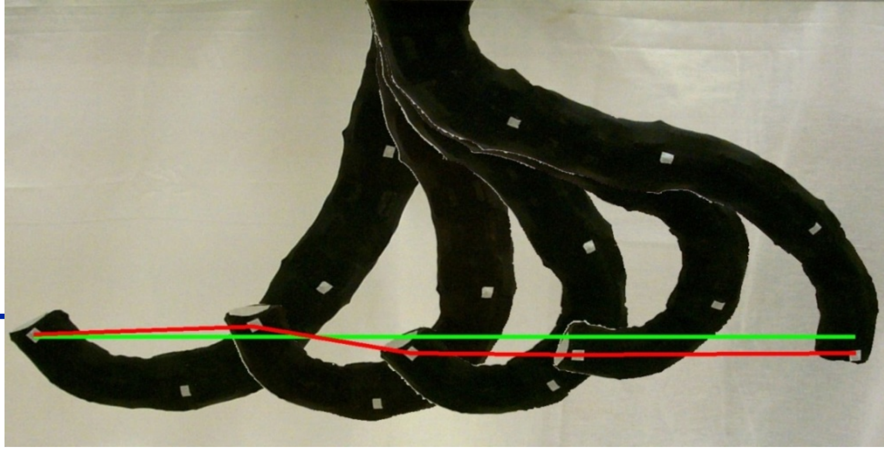
- Howie Choset (CMU, talk earlier today)
- Rob Buckingham (OCR, talk later today)

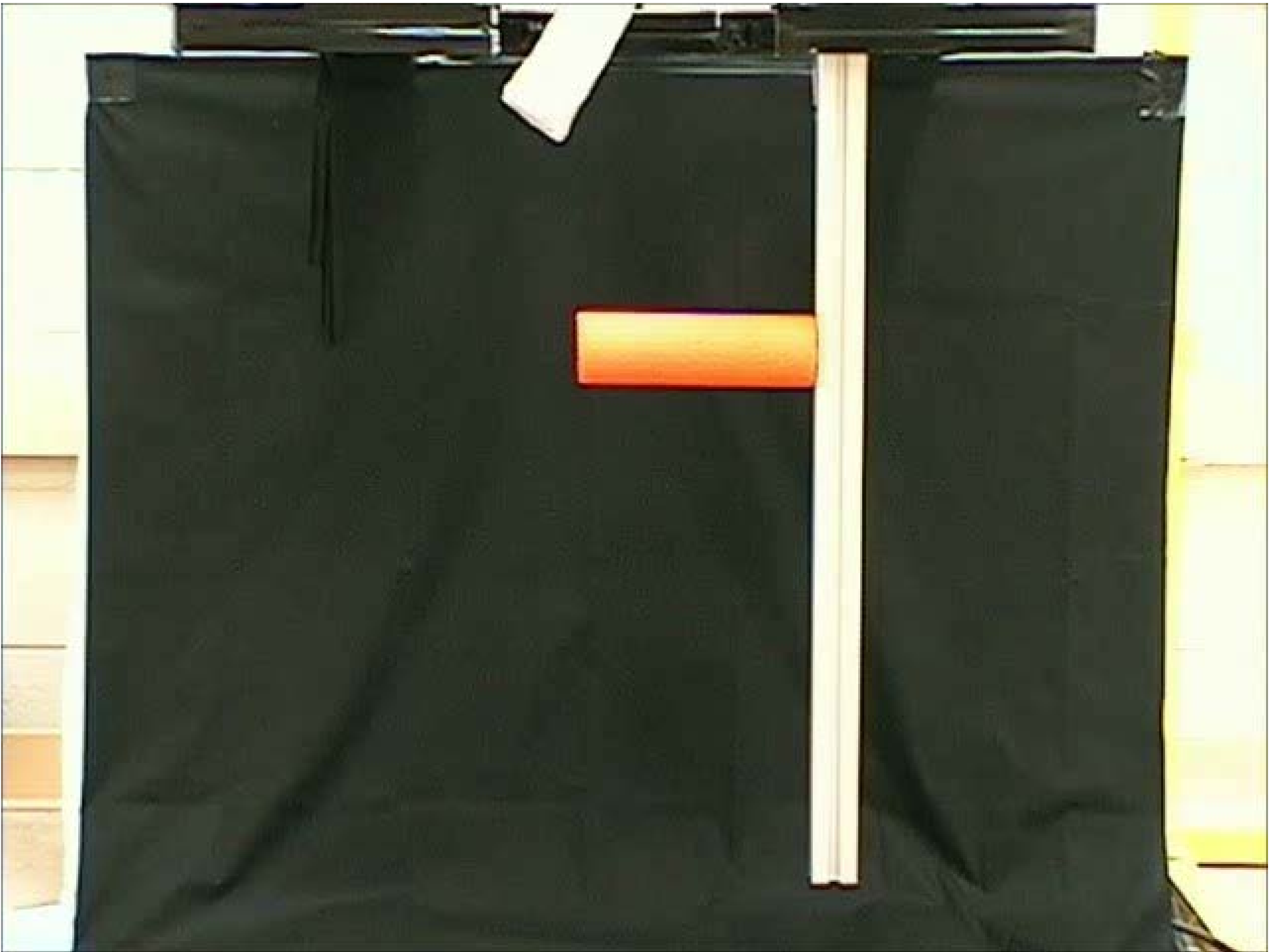
Howie Choset
(CMU)



OC Robotics

Example: Clemson Elephant Trunk





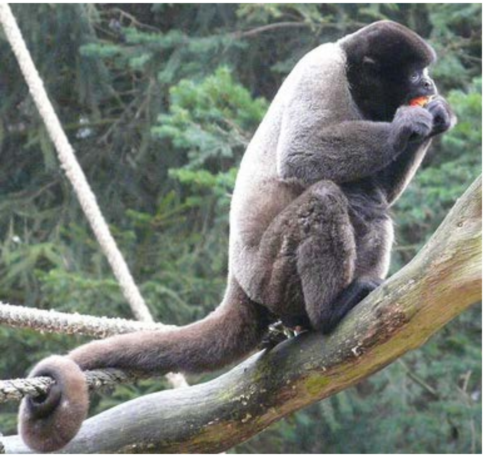
Still rigid components

Soft "Continuum" Robotic Manipulators

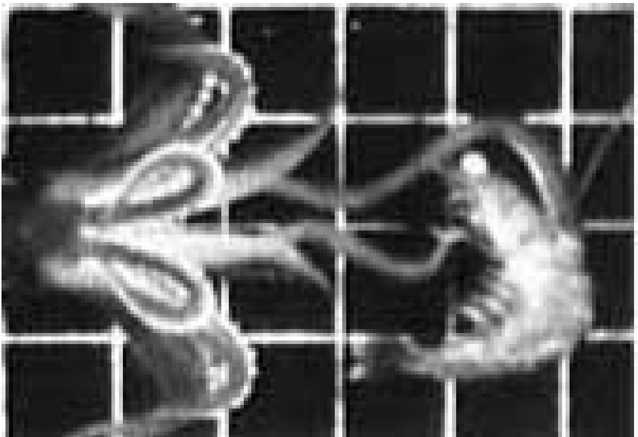
- Inspiration from biology - soft, flexible, continuous appendages ("tongues, trunks, and tentacles")
- Compliant operation in unstructured/cluttered environments
- Rich history, back to 1960's

Natural Continuum Structures

- Exploration, sensing, manipulation



Stability and balance

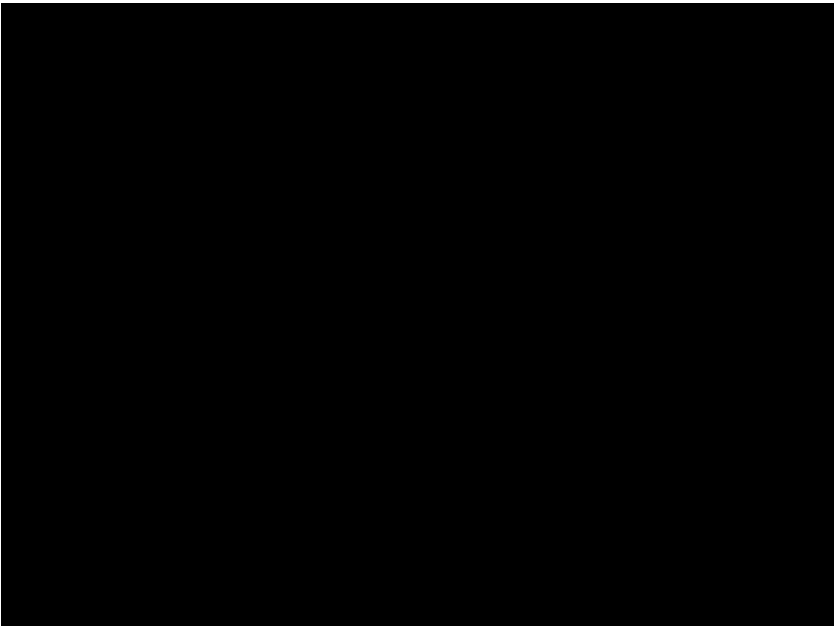


Fast, dynamic target acquisition

Biological Inspiration – Octopus

Remarkable diversity and complexity of movement in soft structure

- At any point on arm:
  - elongation, shortening, bending, torsion, variable stiffness



Roger Hanlon

DARPA/DSO OCTOR Project (2003-07)

Univ. of North Carolina, Chapel Hill

Biomechanics, functional morphology of cephalopods

Marine Biological Lab, Woods Hole:

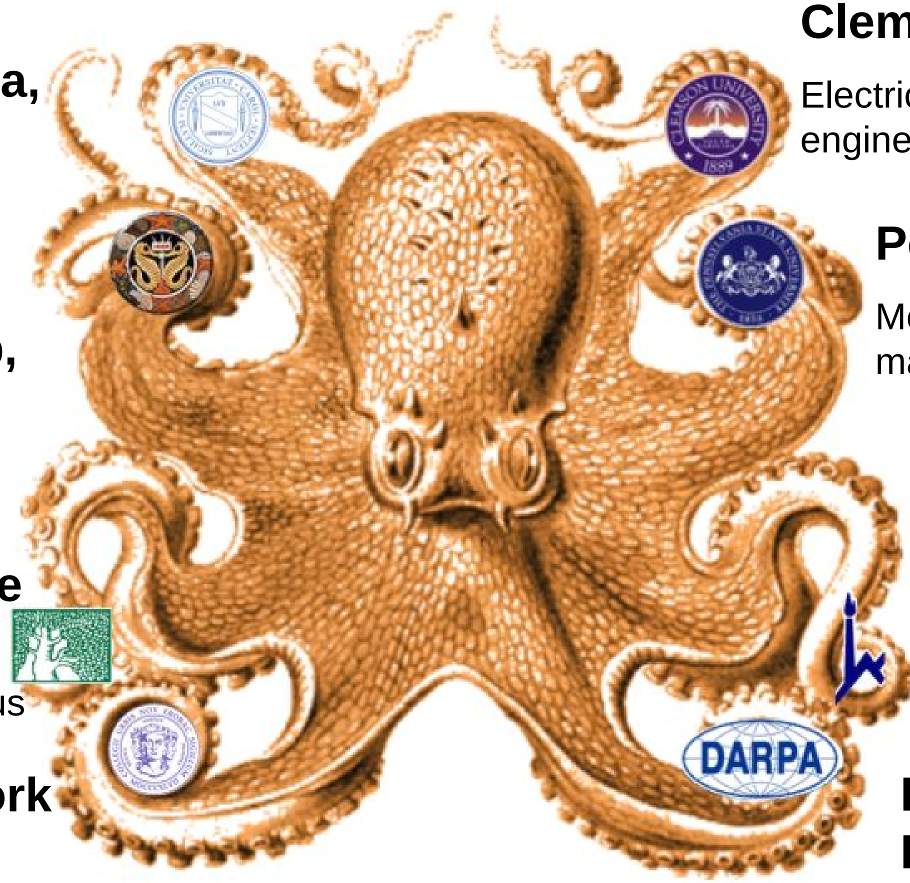
Cephalopod behavior

Weizmann Institute

Mathematical modeling, motion analysis of octopus

City Univ. of New York

Artificial suckers



Clemson University:

Electrical and computer engineering, psychology

Penn State Univ:

Mechanical engineering, materials science

Hebrew University:

Cephalopod neuromuscular control

DARPA BioDynotics Program

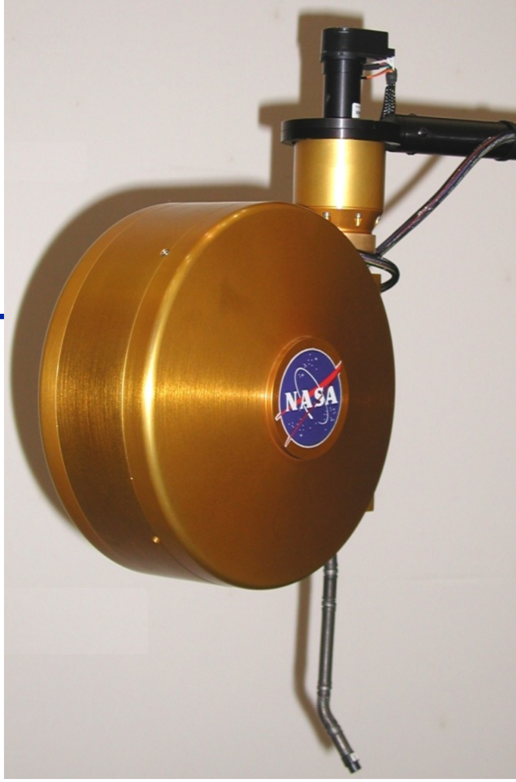
sOft robotiC manipulaTOR (OCTOR)

Example: DARPA Octarm (~2006)

Biological Inspiration: Plants

- In particular, vines

Example: NASA Tendril

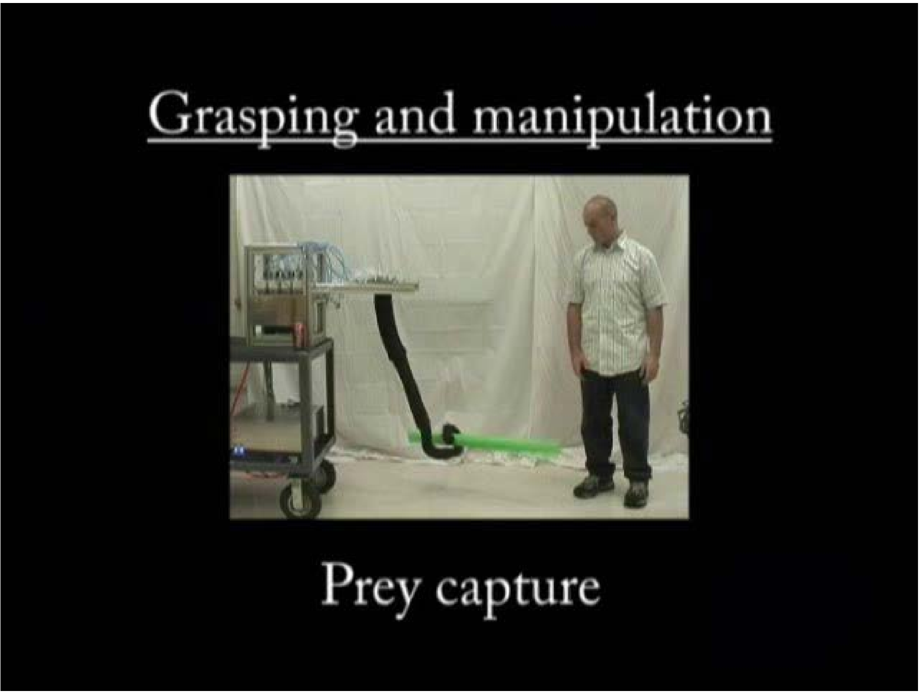


Biological Inspiration - Squid

Brian Mccarty

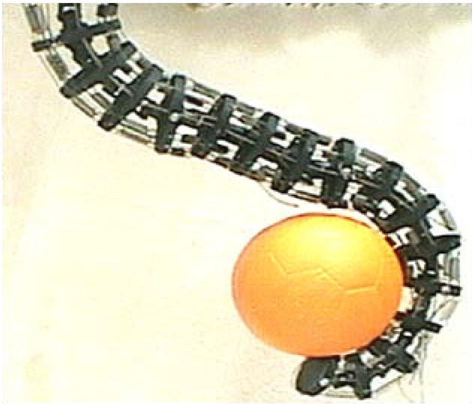
Bill Kier

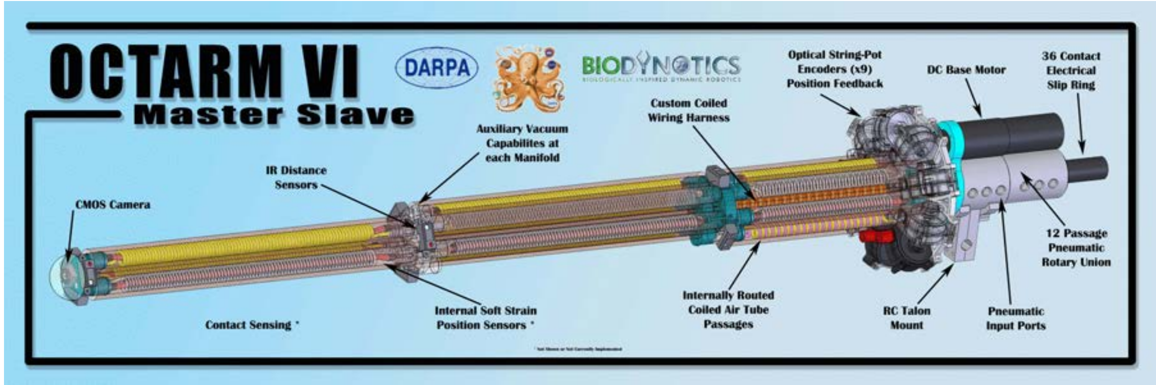
Example: Octarm



How are they Made?

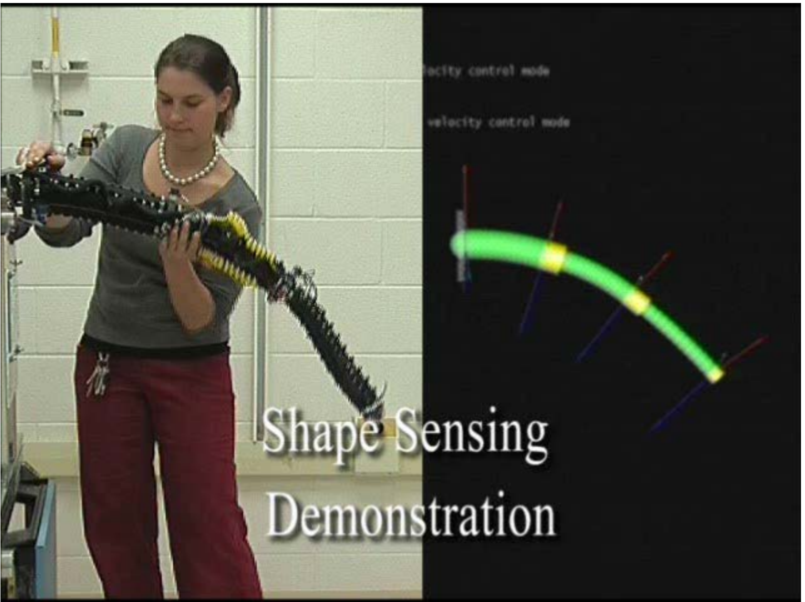
- Fairly wide design space
  - backbone type (segmented, continuum)
  - actuation type (motors/tendons, artificial muscles)
  - compliance/rigidity
  - extension/bending (torsion)
  - operation/control strategy

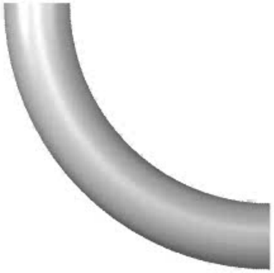


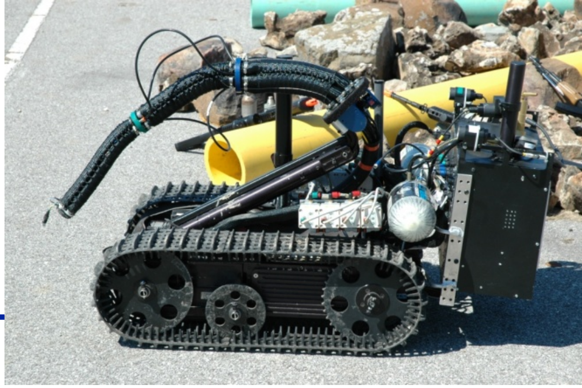


Making Them Work is Not Easy!

- Many degrees of freedom to coordinate, sense
  - Passively/actively controlled
  - non-intuitive movements for operators
- Model and non-model based operation
  - Kinematic models fairly well established
  - Dynamic models emerging







Summary

- New generation of robots corresponding to biological "tongues, trunks, and tentacles"
- Fairly wide design space
- Expanding corresponding body of theory
- Preferred design strongly a function of application

Recent Survey Papers

- R.J. Webster III and B.A. Jones, “Design and Kinematic Modeling of Constant Curvature Continuum Robots: A Review”, *International Journal of Robotics Research*, Vol. 29, No. 13, pp 1661-1683, November 2010.
- D. Trivedi, C.D. Rahn, W.M. Kier, and I.D. Walker, “Soft Robotics: Biological Inspiration, State of the Art, and Future Research”, *Applied Bionics and Biomechanics*, 5(2), pp. 99-117, 2008.